DOCUMENT RESUME

ED 271 203 PS 015 841

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TITLE Model Building: Toward a Constructivist Theory of Learning Mechanisms.
PUB DATE Feb 86
NOTE 31p.; A version of this paper was presented at the Annual Meeting of the American Educational Research Association (Chicago, IL, March 31-April 4, 1985).
PUB TYPE Viewpoints (120) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Cognitive Processes; *Coordination; *Learning Theories; Metaphors; *Models; *Piagetian Theory
IDENTIFIERS *Constructivism

ABSTRACT

This paper outlines a constructivist theory of learning with a more concrete and specific approach to the types of problems addressed in Piaget's equilibration theory. Knowledge, in this constructivist view, results from the subject's transformational activity on the world and his/her real efforts to organize that activity. The first section introduces fundamental implications of the constructivist position which are considered necessary to models of learning mechanisms. Discussion focuses on (1) the construction of knowledge through reflection on praxis in relation to the real world; (2) the nature of the interactive relation between organism and environment; and (3) the person as the primary causal agent in the construction of knowledge. Expanding Piaget's biological metaphor in the direction of systems theory, the second section proposes a constructivist interpretation of the composition of mental models. The discussion leads to the specification of aspects of a mechanism of coordination resulting in the establishment of a new internal control structure in the individual by which actions are "crystallized" into meaning. The final section presents a model of the mechanism of change in representational capacities viewed as action-based models. A three-page list of references concludes the document. (RH)

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ED271203

Model Building: Toward A Constructivist Theory of Learning Mechanisms

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FS 015841

A version of this paper was presented at the annual meeting of the American Educational Research Association, Chicago, April, 1985. Revised February, 1986.

RUNNING HEAD: Constructivist Learning Theory

As the new cognitivism replaced behaviorism as the central theme in American psychology (Gardner, 1985) it also shifted attention away from the traditional concern with learning. Now that cognitive psychology itself has come of age the problem of learning is beginning to reemerge within a new framework of discussions about "knowledge acquisition" (Carey, 1985). However, the new discussion continues to take as its psychological reference point the traditional developmental approach which describes acquisition in terms of sequential states of knowledge leaving the transition between states to the imagination of the reader. Despite the apparent relevance of the topic to educational and research enterprises there continues to be a remarkable lack of theoretical models of the mechanism of knowledge acquisition as a psychological process.

One reason for this gap is that, having accepted mental phenomena, the functionalist orientation of American cognitive psychology has tended to focus research efforts on questions about the processing and use of knowledge to the relative exclusion of the question of how new forms of knowledge are gained. As long as this remained the case many epistemological problems could be relatively backgrounded since one can ask what is done with knowledge at least somewhat separately from asking where it comes from or what it is. However, with the growth of interest in acquisition processes the problem of choosing epistemological sides is thrust back into the foreground since

any position one takes on the origin of knowledge implies an assumption about its nature and vice verse.

The epistemological position known as constructivism is often invoked in cognitivist discussions about learning processes. Broadly speaking, constructivism takes the position that knowledge is the product of an active subject as opposed to the result of a passive reaction to a determining environment. The appeal of this position to cognitivists is due primarily to two sources, both of which represent distinct incompatibilities with behaviorism. One is the humanistic image of the self-actualizing subject projected by constructivism. The other source is the accumulation, over the last few decades, of evidence about the active role of the subject from the study of functional processes such as the generative use of linguistic rules and the phenomenon of over-generalization in children.

However, while the intuition of an active, self-regulating learner is a good starting point, reducing constructivism to the superficial proposition that one is active in learning threatens to trivialize a complex set of ideas. After all, operant conditioning involves an active organism (White, 1968). Constructivist epistemology involves not only the intuition of an action-based knowledge but also a system of implications forming a framework for that proposition. A constructivist theory of learning therefore must be consistent with the implications and not only the raw intuition of action as a basis for knowledge.

The most extensive attempt to construct a theory of acquisition within a constructivist framework has been Piaget's equilibration theory. This model, however, was developed with broad philosophical and historical problems of knowledge in mind. Both researchers and practitioners find its broad functionalist conceptions like assimilation and accommodation too abstract for application to specific situations. The problem of learning mechanisms calls for a more concrete and specific approach to the types of problems addressed by these Piagetian functionalist concepts.

The purpose of this paper is to outline some main aspects of such an approach. The first section of the paper introduces some fundamental implications of the constructivist position which must provide the framework for models of learning mechanisms. The next section proposes a constructivist interpretation of the composition of mental models and the last section presents a model of the mechanism of change in representational capacities viewed as action-based models.

Knowledge and Action In rejecting behaviorism, many cognitivists believe that they have also rejected the epistemological doctrines associated with logical positivism and logical empiricism. However, while it is true that strong versions of environmental determinism have been eliminated, subtler versions remain with us. Logical positivism not only raised the environment to a causal factor in determining behavior

but also posited environmentally derived theory-neutral information while granting to the subject an equally "data-neutral" set of logical operators (Taylor, 1973). Given such a Cartesian dichotomy between the outer world with its information and the inner world which receives and is modified by the information, the most reasonable source of new knowledge is direct perception (Bernstein, 1983). Empiricist theories therefore tended to base knowledge acquisition on an accumulation and manipulation of perceptually encoded primitives. Many current cognitive theories (including inatist positions) which reject older psychological embodiments of empiricist principles, nevertheless retain what Bickhard and Campbell (1985) have called the "perceptual encoding hypothesis" as an implicit theory of acquisition.

Acquisition theories which reflect this viewpoint take the form of "hypothesis testing" or "rule induction" models. Consistent with the positivist division between theory neutral information and data-neutral logical operators, these models all involve one or both of two mechanisms of acquisition: (1) perceptual encoding and (2) pattern matching. In such models, knowledge acquisition amounts to matching the information "patterns" (schemata, rules, "structures") to similar patterns in the world (or in the perceptual field) and, in cases of mismatch, either adjusting for "goodness of fit" or reading in new information via perceptual encoding. Thus the mental set of

information is essentially a copy of a preexisting environmental set. Whether one chooses to view the term "information" metaphorically or grants it an ontological status makes little difference since either case implies apriori external "patterns."

The role of human agency in such models is reduced to guessing at "hypotheses" and testing these in a match-adjust process. The organism's actions function to bring it into harmony with an environment which remains the determining factor in the form which the new knowledge takes. This sort of homeostatic adjustment model is clearly inconsistent with the post-positivist views which support most current models of cognitive and social macro-development but it remains the norm in models of learning processes.

If constructivist epistemology is reduced simply to the proposition that the subject is active, the above versions of environmental determinism can still be allowed since pattern matching is an "active" process. To provide a real alternative the full implications of the idea that knowledge is abstracted from human action, not from perceptual encodings, must be considered. These implications may be viewed as falling into three mutually dependent categories.

(1) Reflective Abstraction. Higher forms of knowledge are derived by abstraction from one's action on the world, not simply

by direct perception. Although the world is considered as real and independent of thought, it is not viewed as containing information or "patterns" existing prior to the organizing activity of the person (the so called doctrine of "immaculate perception"). On the contrary, information is always the product of the interaction of the world and the organizing action of the person. Information is constructed by reflection on praxis in relation to the real world. The source of new information then is partly internal in a non-trivial sense. That is, the organism is responsible for creativity or novelty in the synthesis of knowledge as opposed to simply performing operations on input material.

(2) Interactionism. The above considerations imply that the relation between the organism and the environment must be interactive, again, in a non-trivial sense. That is, the organism is not simply receptive to encodings anymore than it is simply reactive to stimuli. It actively seeks to alter or transform the world in order to achieve self-initiated goals. The environment, in turn, offers constraints to the subject's organizing activity by resisting efforts to change it, forcing the organism to reorganize itself in order to devise new means of approach. The environment is therefore indispensable to the process of knowledge acquisition but does not simply act as a "trigger" to set off automatic processes in a helpless organism anymore than it offers prepackaged information to be passively

scanned.

(3) Human Agency. The person is the primary causal agent in the construction of knowledge. The synthesis of knowledge is due to the activity of the person and not to the selective action of the environment on the person. Thus the changes which a person makes are not simply "adaptive" in the mechanistic sense which sees change as an ever increasing "goodness-of-fit" to the environment. In the first place, organisms choose the aspects of the environment with which they interact. Secondly, organisms are free to make use of its organizing capacities in "non-adaptive" ways such as play, fantasy and art which weave back into and enrich the whole of knowledge construction.

Cognitivism often associate the term "constructivist" with one or another of the above positions. We argue that each point implies the others and that the constructivist position cannot be adequately represented by any one of them singly. For example, the idea that knowledge has a partial source within the organism reduces to inatism if not considered in relation to the complexity of interaction with the world. Similarly, interactionism is necessary but not sufficient to constructivism since the non-homeostatic nature of the subject's agency in the interaction drives the production of newness in the means of approach. If the organism simply adjusts itself to prevailing conditions then change is possible only under conditions of environmental pressure--a reaffirmation of environmental

determinism. Furthermore, neither transformational human agency nor interactionism will sustain the position in the absence of reflective abstraction since the default value here is perceptual encoding. Since perceptual encoding is both passive and trivially interactive, it cannot support the other dimensions of constructivism.

Each of the problems posed here have often been raised and discussed in the past. The point which we wish to emphasize again is that in order to sustain a consistent constructivism the three dimensions of the problem we have discussed must be taken together as a minimum in psychological models which attempt to make use of a constructivist epistemology.

Expanding the Biological Metaphor

The biological metaphor used by Piaget is especially helpful in working within a constructivist framework because it offers ways of representing the relations between the above dimensions which are difficult to carry in mechanistic metaphors. We will therefore be arguing that the process of mental acquisition is like the process of biological adaptation in certain fundamental ways. However, we do not mean to advocate a biological reductionism. The acquisition of mental functions is clearly inseparable from cultural context. Yet, if environmental determinism is to be avoided in descriptions of the acquisition process then the role of the human agent must be given proper

credit. This requires a description of the contribution of the person qua organism needs to be woven into descriptions of cultural acquisitions. Our purpose here is to focus on the organismic side in order to bring it into greater clarity rather than to separate it from its cultural embedding.

Although Piaget (1977) developed the functional aspects of the biological metaphor into an abstract theory of equilibration, we would like to begin with a simple qualitative model on which the abstractions are based (Piaget, 1952). In the classic biological metaphor organismic reorganizations are viewed as the result of progressive self regulation operating in attempts to achieve goals of affecting or transforming the world. Each action on the world involves both and end or goal and a means or procedure for reaching the goal. The specific type of means employed is a function of the way the organism is currently organized along with the resistance offered by the environment to transformational activity. For example, physically, a hand organized to have opposable thumbs allows for the strategy of grasping in cases where the object to be grasped is of a manageable size.

At the level of physical organization, a change in organization requires an evolutionary step as in the case documented by Gould (1980) of the evolution of a "thumb" in pandas through the adaptation of a wrist bone to serve the grasping function. In humans, reorganizations of both motor and

psychological organizations can take place within individuals. The problem of change in psychological organization then may be viewed as the problem of describing the mechanisms by which such reorganizations take place.

Before entering on the question of psychological changes several aspects of the above discussion should be emphasized. First, the description of adaptation requires that the organism be engaged with the world but not that it conform to any preestablished "problem" presented to the organism by the environment. On the contrary, the "problem" is set by the organism in its choice of ends which themselves are not static but involve transformation of conditions in the world. Second, the adaptation described is not simply homeostatic. That is, the self regulation involves more than a return to a state of rest or equilibrium with the world. If an adaptation aimed at transforming the environment is successful then there is an effective change in the environment as well as an effective reorganization of the organism.

Anyone familiar with the Piagetian notion of "progressive" equilibration (Piaget, 1977) will find nothing new in the above considerations. However, it is necessary to stress these aspects of the model in order to avoid confusion in the next stage of the argument which involves an extension of the biological metaphor into systems theory. Systems theory is generally associated with information processing and computational models of cognition

because of the role of cybernetic models in the early development of these theories. Von Bertalanffy (1968), however, distinguished between two classes of open systems. The first is the homeostatic equilibrium system at the base of TOTE systems and Turing machines (Miller, Gallanter and Pribram, 1960) are special case of the second Non-homeostatic systems which he claimed form the general case and characterize organic systems are capable of changing their organization with respect to the environment as well as adjusting to the environments demands. This latter sense of systems theory provides a model for describing at the psychological level the kind of progressive adaptation[1] discussed above in terms of physical evolution.

Inhelder and Piaget (1980) have provided an inroad to expanding the biological metaphor in terms of systems theory. Systems are viewed in terms of bipolar tendencies in interaction. The major bipolarity is between the tendency toward procedure or action upon the world and structure, the tendency to organize. Note that this is a functional distinction between two inseparable but opposing tendencies, not a dichotomy between action and structure reminiscent of the French structuralist tradition with which Piaget's earlier work has often been connected. Procedures are actions carried out in time and space

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1. By "progressive" here we mean to imply only a qualitative change based on the history of the organism and not a teleological assumption about the direction of the change.

on real events to reach a variety of external goals. Procedures allow for success with a specific environmental resistance. They involve sequences of actions performed in an attempt to transform the situation to meet a desired goal.

The tendency to structure or organize preserves what has been "learned" in the use of procedures in a situation by retention of the form of the system which supported the procedures. The organization of the system functions like the organization of the hand in allowing grasping and in "remembering" that there are things to be grasped. The relation between inner and outer, form and function in the system is therefore not dichotomous but continuous and bipolar.

Since there is not a strict division between form and function there is not disparity between action and thought. The structural pole of the interaction is itself a form of organismic activity. However, rather than being directed toward sequential, spatio-temporal sequences in the world, the structural activity functions to draw together a number of activities simultaneously into a systematic pattern. Such "internal" actions of organizing are fundamentally atemporal as opposed to temporally occurring external actions. In a sense, the inner atemporal tendency "generalizes" the particular context specific acts by preserving their general form in the organization of the system's ability to produce them. In this sense, then, the structural pole "averages" actions across contexts.

In order to describe mechanisms of change in such systems it is necessary to describe the process by which actions are drawn together into a new systematic organization. At the sensori-motor level Piaget proposed the process of reciprocal assimilation or informally, coordination of action patterns. The bipolar system provides a model for thinking about reciprocal assimilation more generally. Since the inner or structuring pole involves the activity of systematizing it requires a special category of actions, those which are taken on other actions. That is, the activity of controlling the effects of outer actions requires that inner systems connected with these actions be made to function in concert. Coordination or reciprocal assimilation therefore is fundamentally a control function. The result of an act of coordination is the establishment of a new control structure which can now be seen to be the general form of all internal organization.

Although Piaget (1953, 1954) has provided numerous illustrations of this process in the sensori-motor constructions of infants a trivial but familiar example will serve to concretize the discussion. Asking a child (or adult) to rub her stomach while patting her head often produces perplexity at first. The acts can be performed successively but not in concert. Gradually, through attempts at controlling the outer actions the two movement patterns are brought together simultaneously. What were previously two separate actions become

functionally united. The internal efforts at control or coordination result in a new inner control structure which governs both actions while effectively extending or "generalizing" each beyond its original locus of efficacy.

More commonly we bring our actions together "around" some aspects of reality that we wish to alter or affect. These are more often social regularities than objects but for the sake of simplicity we will use the example of a bicycle. In order to learn to manipulate the bicycle to do your bidding many disparate movements must be brought simultaneously under control. Reciprocal assimilations bring new control structures into being which support a qualitatively new pattern of actions.

In an important sense, such actions are not merely organized but are organized to ride the bicycle. In other words, the inner control structures are related to outer events by virtue of having been invented to control our attempts to influence them. Insofar as these inner structures preserve and generalize the specific actions across situations and times then they may be said to have "reference" to classes of potential events.

Mandler (1963), acknowledging his debt to Piaget and others, described a similar process in terms of the formation of an "inner analogue" or "analogic structure" which becomes the basis for storing information across spatio-temporal contexts. However, Mandler's analogues, based on a homeostatic regulation

model similar to TOTE (Miller,Gallanter and Pribram, 1960) remained "temporal and probabilistic linkages of input and output which are available in functional units." That is they were seen to operate in a sequential manner to anticipate and "select" appropriate responses to stimuli. Analogues thus serve a representational function which guides actions. However, since these structures were viewed as sequential and selective they could only allow for choice in responding to the environment by sampling from pools of "strategies." Furthermore, analogues cannot explain the invention of new representations or strategies since they are limited to anticipating and selecting ready made responses. This limitation is shared by all notions of structure based on the homeostatic regulation model and therefore by computational models of representation in general.

By contrast, the inner structurations which we are describing differ in that the coordinating activity results in an atemporal, non-sequential character. As we have seen, the control structure resulting from coordination has two significant features, (1) that it refers generally as opposed to specifically to types of actions and (2) that it governs a qualitatively new kind of action. This notion of the representational function of inner organizing activity is more akin to the Vygotskian conception of a "semantic reference system" (Vygotsky, 1962, Wertsch, 1985) in which inner representations are seen as "condensations" of external social activities, especially

speech. Similarly, in our view, meaning is viewed as derived from action, as having reference to the possibility of transformational action on the world and as creative in its generalizing capacity. As Zaporozhets put it, "Meaning is the crystal of action" (Zinchencko and Davydov, 1985). We argue that the mechanism of coordination is the vehicle of this crystalization.

Before discussing the implications of these views for mental acquisition processes it will be helpful to bring out four important aspects of the mechanism of coordination which we have been describing.

(1) There is a distinct quality of coordination which leads to an atemporal tendency of the structural side of the bipolar system. While external actions aim to effect the world and take a spatio-temporal form, internal actions aim to bring other actions together and thus tend toward the simultaneous and compound.

(2) The outer and inner tendencies differ in their aims but are not divided into separate "competence" and "performance" systems. When coordination is attempted the locus of activity shifts from the external to the internal. When this shift occurs the goal is no longer an external sequence but an internal organizing or pulling together.

(3) The coordination process results in an effective

interiorization in the sense that there now exists an aspect of the inner control structure which corresponds to but does not copy the sort of external resistances for which it compensates. The external now has an inner correlate in the control structure or system of coordinated action patterns.

(4) Once a control structure is stabilized--that is once one has established a new stable action pattern the new pattern can serve as the basis for further organization. For instance, once one has established rubbing/patting, one can bring the new system into coordination with other movements such as walking which if attempted prior to completion of the coordination would simply have caused the breakdown of the new system. When a stable pattern has been formed by coordination it functions externally as a single action. New coordinations can therefore take place as actions upon the old system of actions. In this sense the older stabilized actions serve as an "object" upon which further organization may be based.

(5) Each coordination, once stabilized, results in a qualitative change in action capacity. The process of establishing the coordination may require gradual action and appear continuous but the eventual result is a qualitative shift. The new organization is obviously based on the old and therefore the process is both continuous and discontinuous with previous development of the system.

Mental Models

Up to this point the discussion has dealt with characteristics of organic systems in general and questions about specifically mental processes have not been directly addressed. In order to do so the notion of "representation" which has been dealt with very loosely needs some clarification. Following Piaget, we assume that the semiotic function constitutes the extension of the inner structurations to the level of mental organization. The general features of the process remain similar at this level but are extended to ever widening cultural contexts.

Despite the cultural embeddedness of thought at the mental level it retains its essentially action based character. As indicated above, the conserving or generalizing element of the inner structurings serves to anticipate the possibility of actions affecting the world. Our representation of reality is therefore a function of our anticipated changes of that reality. The increasingly differentiated inner structures become a system of interconnected reference to world events. Representation is therefore active in two senses, (1) that it constitutes a differentiation of one pole of the bipolarity of organismic action and (2) that it is used actively in real situations to transform the situation.

To emphasize this point we distinguish between two usages of

the word representation. In the first the term indicates an instantiation of a category as in

1. Oranges were well represented in the bowl

In a second usage one refers to a person's active, "real time" act of representing:

2. She represented the orange with a circular gesture.

The first sentence corresponds to psychological usages such as "arithmetical knowledge is represented in memory." The second corresponds to the sort of representation employed in active thinking and problem solving. The first usage is essentially a convenient reification of the second and is valuable for purposes of formal analysis. Our distinction however is warranted because the extensive use of the formal sense of the term often obscures the meaning of the active sense.

We use the metaphor of the mental model (Johnson-Laird, 1983) in discussing this sort of representation at the mental level of functioning. In doing so we wish to emphasize the active role of the subject in constructing representations in action contexts. The metaphor of the mental model also helps to emphasize a strong distinction (but not separation) between conscious representational activity and procedural knowledge which remains pre- or unconscious. The latter is viewed here as a resource for the reflective activity involved in constructing new models. The construction of new knowledge, from this point

of view, is an adaptation, via mechanisms similar to those described earlier, in which mental modeling capacity is reorganized.

The "material" of mental models

The metaphor of the mental model is an especially good one for a constructivist interpretation since the idea of making a "model" does not easily conform to objectivist notions of direct perceptual encodings. A model naturally suggests an interpretationism along hermeneutical lines yet it also allows for a conception of valid and increasingly intimate reflection of reality.

However, if perceptually encoded primitives are rejected as the source of the material of mental representation the first problem is to say what is used to make our models of the world. Piaget argued throughout his writings on perception, mental imagery and memory that the "contents" of thought are not separable from its form because both emerge from the process of generalization characteristic of the organizational pole of action. Perception, on this view, is a special case of organismic activities (the perceptual field itself having been actively constructed from coordination of sensori-motor tableau) which actively compensate and interpret sensorial disturbances with the help of the action-based meaning system. However, perception is not prior to meaning either in ontogenesis or in

function. Perception is enmeshed with and acts in concert with the action-referenced meaning system but is not considered a linear source of information from which meaning is subsequently abstracted.

Given these considerations, some form of interiorized action--the inner "crystals of action"--must be thought of as the source of primitive terms in the construction of mental models. As we noted above, interiorization involves the stabilization of an ability system or control structure which can serve as the basis for further organizing efforts and which refers to classes of outer possibilities. Such stabilizations can be interpreted as the mechanism by which understanding becomes "figurative" in the above sense. To the extent that control structures stabilize they become capable of reflecting stability in the world which they seek to organize and, at the same time, become available as one source of differentiated primitive terms. This is basically Piaget's (1971) position on the nature of mental imagery. Experimental psychological studies of mental imagery have for a long time acknowledged the quasi-perceptual character of images (Kosslyn, 1983) but cognitive theorists have been reticent in rejecting at least an implicit perceptual abstraction process as the primary source of mental primitives. This is partly due to the failure to take seriously the alternative proposal of action-based primitives advanced by Piaget. Accepting this proposal, in our view, is essential to an understanding of

knowledge acquisition in constructivist terms.

In the remainder of this discussion we will use the term "stabile" to refer to such inner systems used as objects at the mental level. From this perspective, the scheme of the permanent object would constitute the first stabile. However, while the stabile is clearly a "scheme" in Piaget's sense, it is a specific kind of scheme in our view: One which has reached stability in a process of development and which is utilized as a part of a repertoire of mental primitives in the construction of mental models.

A stabile is in a certain sense "modular" (at least in the sense of individuated and differentiated) but it differs from Fodor's conception of modules in several regards including (1) the historical nature of it's construction by which is implied it's sensitivity to the variegation of the environment and its source in prior praxis and (2) it's non-computational nature by which is implied the atemporality and generalizing character of the systematization as opposed to the temporal/sequential nature of computational structures.

Model Building

A growing literature on expert/novice shifts has brought to light a wealth of phenomenological descriptions of changes in mental modeling (DiSessa, 1983) but has not provided explanatory mechanisms to account for such change from the point of view of

the organism. The tradition of Genevan microanalysis of problem solving stemming from the landmark paper by Karmiloff-Smith and Inhelder (1974) has concentrated on descriptions of successions of "theories" in problem solving but has not succeeded in tying such descriptions to functional mechanisms in the same way that Piaget's sensori-motor work does for the succession of sensori-motor acquisitions. One reason for this lack seems to be a missing emphasis, at the conceptual level, of the agentive role of the subject in the constructions. In particular, the mechanism of active coordination or reciprocal assimilation tends to be down-played in descriptions of mental acquisitions. The open systems model and the construct of "stabile" provide a means of thinking about the role of coordination at the mental level.

As we attempted to show earlier, a constructivist account of mental change must provide a description of human agency, non-trivial interaction and abstraction from action patterns. Descriptions involving only successive outer actions or alternatively successive inner theories leave unspecified the nature of the interaction between the two and the role of the person in bringing them together.

The nature of this interaction can been thought of in terms of an analogy to the bicycle example mentioned above. Substituting a problem solving situation for the attempt to ride the bicycle, the subject's representation of the problem can be conceived of as a currently constituted stabile or mental

organization of actions "around" the problem. In the case of the bicycle the initial organization came about when the subject coordinated sets of independent actions creating a higher order control structure "internally" which supports and references new behavior "externally." This process can be conceived of a "building" a system of actions around an external regularity.

Changes in mental models of problem situations can be conceived of analogously as building an organization of mental actions around events and social regularities in the form of inner control structures which regulate our behavior in the situation. The primitives in the construction process are stabiles and the mechanism of their synthesis is the activity of coordination.

For example, in considering a generic problem solving situation, the subject's current representation of the problem is inadequate to guide behavior since it anticipates only part of the action of solution. Typically in such a situation subject's explore the problem trying out various ways of conceiving it and using the strategies suggested by different ideas. However, as long as the problem eludes solution no single mode of representation is comprehensive enough to suggest a solution. Thus current stabiles, used <u>successively</u> are capable of representing only limited aspects of the situation. Behavior at this point is generally reminiscent of the rubbing/patting dilemma: Oscillation between alternative partial approaches.

The advent of a new modeling takes place when the subject shifts the primary emphasis of activity from an "external" orientation of the system to an "inner" coordinating effort. Stabiles which have been used successively in attempts to grasp the situation are coordinated in a process analogous to the coordination of rubbing/patting. The resulting model is "comprehensive" in the sense that it represents simultaneously aspects of the situation which previously could only be represented successively. With the establishment of a new model or more comprehensive stabile the system's locus of activity again shifts to the external orientation where the qualitatively new model supports successful behavior.

In conclusion, several features of the process we have described can be noted. (1) The change in understanding involves a qualitative shift. The process may be gradual but the result is a qualitatively new representation which supports a new behavior. (2) There is a concrete mechanism linking the old to the new. The new representation is constructed by coordination of real previously existing stabiles. Unlike hypothesis testing models which simply assert a selection process operating on a pool of "hypotheses" of unknown origin, the coordination mechanism allows a linkage of past to present in the process of generation. (3) The new representation is constructed in relation to and in order to better understand the environment and it therefore reflects reality without being reduced to an

objectivist copy or environmentally determined response. (4) The new representation tends toward atemporality in that it simultaneously unites what were previously successively applied understandings. (5) The subject is the primary agent in the construction of the new understanding, weaving environmental and historical factors together in attempts to realize changes in the world.

The latter point holds the greatest significance for educational considerations. Knowledge, in our model results from the subject's transformational activity on the world and his or her real efforts to organize that activity. The organism is not only active in conforming to the environment as in functionalist theories which Von Glasersfeld has labeled "trivial constructivism." Rather, if the world leaves an "impression" on us it is because we ourselves restructure our actions in order to organize reality.

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